

## Slip Frequency Control with Hysteresis Current Controller for Single Phase Induction Motor Drives

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### ABSTRACT

**This paper proposes a closed-loop control strategy to control the speed of a single phase induction motor (IM). The control strategy employs Slip Frequency Control technique to independently control the currents in two stator windings and make them follow a predefined sinusoidal waveform. The current flowing through the two windings are controlled with the help of a hysteresis current controller. The proposed scheme is successful in controlling the speed of single phase IM and it is clear from the simulation results.**

**Keywords** –Hysteresis current controller, single phase induction motor (IM), slip frequency control (SFC), Variable frequency drive.

### I. INTRODUCTION

Adding a variable frequency drive (VFD) to a motor driven system can offer potential energy savings in the system where the load varies with time. VFDs belong to a category of equipment called adjustable speed drives or variable speed drives. The operating speed of a motor connected to a VFD is varied by changing the frequency of the motor supply voltage [1]. This allows continuous process speed control. Speed control is achieved in the inverter driven induction motor by means of variable frequency. Apart from frequency the applied voltage is varied, to keep the air gap flux constant and thus prevents saturation [2].

Open loop speed control of the two phase IM using two single-phase half-bridge inverters operated in the square wave mode [5]. With a square wave voltage applied at the motor terminals, the motor terminal voltage and hence line current has high harmonic content. This resulted in

increased torque harmonics as well as reduced motor overall efficiency. To avoid such problem, a phase difference angle (PDA) control employing the pulse width modulation (PWM) selective harmonic elimination technique has been

used [3] and [4]. Although the PDA control scheme has been successful in operating the two phase motor with a variable frequency, it is complex to implement. Moreover, high-torque pulsations result when the phase angle between the motor terminal voltages is other than  $90^\circ$ . Torque pulsations become even more pronounced when the phase angle is small.

Space vector closed loop speed control of symmetrical two phase Induction Motors [6]. Though successful in controlling the speed of the motor, this control scheme has not been optimal in driving the unsymmetrical two phase IM since it neglects the zero sequence components of the voltages/currents. Taking the zero sequence components into account has made the implementation of the digital current controller complex.

Rotor flux oriented space vector control of unsymmetrical two phase Induction Motor [7]. Although this scheme produces a high dynamic performance drive, yet it is computationally intense. Consequently, it requires high power microcontroller or microprocessor for its implementation.

The slip frequency control technique to independently control the stator currents of both the main and auxiliary windings of a two phase

induction motor [8]. By maintaining certain operating conditions, the proposed control scheme reduces the inherent torque oscillations of the unsymmetrical IM and thus making it behave like its balanced counterpart.

Vector control strategies for single phase motor drive systems operating with two windings are discussed in [9]. A model is proposed and is used to derive control laws for single phase induction motor drive systems. Such model is also used to introduce the double sequence controller

## II. PROPOSED DRIVE SYSTEM

The schematic representation of the proposed control strategy is shown in Fig.1. The Slip Frequency Control strategy is used in order to realize single phase IM drive system and to provide them with a high dynamic performance. It consists of two feedback loops, an inner current loop and an outer speed feedback loop. These feedback loops helps us to control the stator currents as well as the motor speed. Initially the actual motor speed  $\omega_m$  is compared with its reference signal  $\omega_{ref}$  to produce the error signal  $\omega_{err}$ . The error signal  $\omega_{err}$  is conditioned by the proportional integral derivative (PID) controller to produce the slip frequency,  $\omega_{sL}$ .

The value of  $\omega_{sL}$  is used to obtain the magnitude of the commanding current in the main winding ( $|I_1|$ ). The magnitude of the commanding current in the auxiliary winding ( $|I_2|$ ) is obtained by multiplying  $|I_1|$  by the ratio "a." It is the ratio between the number of turns in the two windings of the stator. Then,  $\omega_{sL}$  is added to the motor actual speed  $\omega_m$  to produce  $\omega$ . The variable  $\omega$  is then multiplied by the number of motor pole pairs to produce the inverter output frequency  $\omega_s$ . The values of  $\omega_s$  along with  $|I_1|$  and  $|I_2|$  are used to determine the reference waveforms of the current in the main ( $i_{1,ref}$ ) and auxiliary windings ( $i_{2,ref}$ ) respectively.

Finally, the actual stator currents are compared with their respective reference waveforms, ( $i_{1,ref}$  and  $i_{2,ref}$ ) in a hysteresis current comparator. The output of the hysteresis current comparator of the auxiliary winding is used to control the inverter switching devices  $S_1$  and  $S_2$ . Similarly, the output of the hysteresis current controller of the main winding is used to control the inverter switches  $S_3$  and  $S_4$ . Hence, the duration of switching of each of the four devices is modulated such that the error between the actual motor speed and the reference speed is reduced.

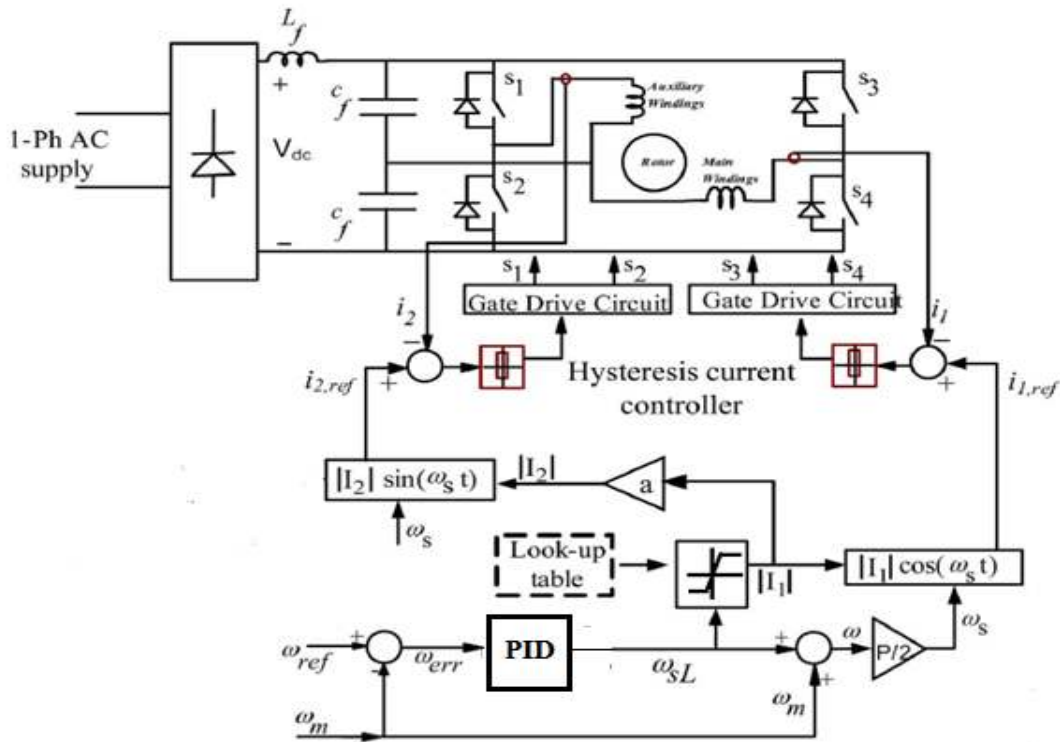


Figure 1. Schematic of proposed system

### III. VARIABLE FREQUENCY DRIVES

A variable frequency drive (VFD) used in a motor driven system can ensure energy savings in a system in which the load varies with time. VFDs belong to a group of equipment called adjustable speed drives or variable speed drives. The speed of the motor connected to a VFD is varied by changing the frequency of the motor supply voltage. This allows continuous control of speed. A VFD converts 50 Hz power to a new frequency with the help of a rectifier stage and an inverter stage. The conversion process includes three functions, A full wave solid-state rectifier converts three-phase 50 Hz power from a standard or higher utility supply to either fixed or variable DC voltage. The system can use transformers if higher supply voltages are required. Electronic switches like power transistors or thyristors are used to switch the rectified DC voltage, and generate a current or voltage waveform at the desired frequency. The amount of deviation depends on the

design of the inverter and filter. Control system is an electronic circuit receives feedback information from the driven motor and adjusts the output voltage or frequency to the desired values. Normally the output voltage is controlled to produce a constant ratio between the voltage and frequency (V/Hz). Controllers can incorporate many complex control functions

### IV. PID CONTROLLER

The PID controller is a device which produces an output signal consisting of three terms - one proportional to input signal, another one proportional to integral of input signal and the third one proportional to the derivative of input signal. Proportional action acts according to the changes in error. Integral action is slower but removes deviation of the plant's output from the reference. Derivative action speeds up the system response by adding in control action proportional to the rate of

change of the feedback error. Consequently this is susceptible to noise in the error signal, which limits the derivative gain.[10] When noise signals are present larger values of  $K_P$  and  $K_I$  (smaller  $T_I$ ) is to be used than possible in pure PI regulators, but large values of derivative gain ( $K_D$ ) will cause instability.

## V. HYSTERESIS CURRENT CONTROLLER

## VI. SIMULATION RESULTS

Hysteresis Current Control is an instantaneous feedback system which detects the current error and produces directly the drive commands for the switches when the error exceeds a specified band. The advantages of this technique are simplicity, better accuracy, robustness and a fast response speed that is limited only by the switching speed and load time constant. In hysteresis current controller the current is controlled within a narrow band of excursion from its desired value.

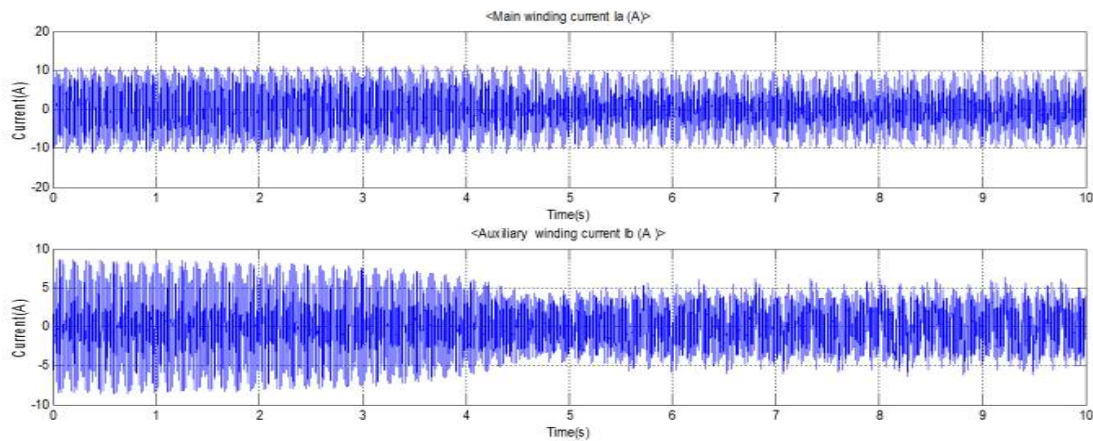
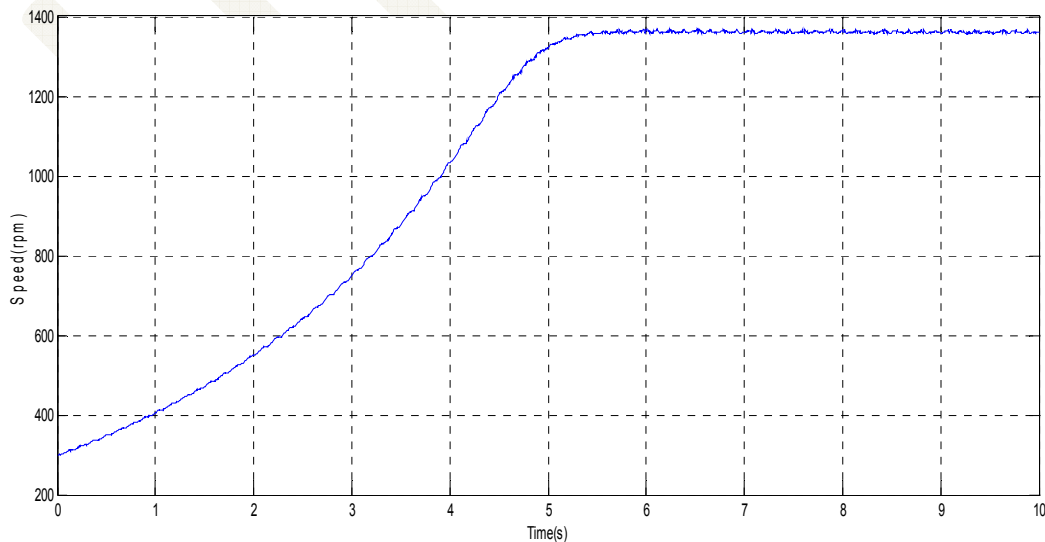


Figure 2. Simulation results of main and auxiliary windings



**Figure 3. Simulation results of motor speed****VII. CONCLUSION**

A single phase Induction Motor drive system with high dynamic performance has been realized. The proposed drive system employs the slip frequency scheme to independently control the currents in the two stator windings of the single phase Induction Motor. The SFC scheme helps to achieve continuous control of speed. The proposed scheme has the following advantages

- i. Limits the motor line current during transient and dynamic stages.
- ii. Reduces the rating of the power inverter, and hence, its cost.
- iii. Fast transient and dynamic responses.
- iv. Highly reliable

The proposed control strategy can be potentially extended to three phase motor drives when the three phase IM loses one of its windings.

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